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Near-Field Antenna Testing Using the Hewlett Packard 8510 Automated Network Analyzer

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NEAR-FIELD ANTENNA TESTING USING THE HEWLETT PACKARD 8510

AUTOMATED NETWORK ANALYZER

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SUMMARY

Near-Field antenna measurements were made using a Hewlett Packard 8510 automated network analyzer. This system features measurement sensitivity better than -90 dBm at measurement speeds of one data point per millisecond in the fast data acquisition mode. The system was configured using external, even harmonic mixers and a fiber optic distributed local oscillator signal. Additionally, the time domain capability of the HP8510, made it possible to generate far-field diagnostic results immediately after data acquisition without the use of an external computer.

INTRODUCTION

Near-field antenna measurements of large, high frequency antennas require a receiver that has good sensitivity, high stability, and quick data acquisition. These capabilities are necessary because the signal level received by a near-field probe is generally very low when testing a large, high frequency antenna due to the great difference in aperture area between the antenna under test (AUT) and the near-field probe. Also, it is desirable to minimize the measurement time of the testing so as to minimize problems with receiver and/ or RF/LO source drift.

NASA's Lewis Research Center has been making near-field antenna measurements on large, high frequency antennas with its planar, horizontal boresite near-field scanner for several years. As a result of the experience gained through experimentation, it was decided to upgrade the facility, particularly the microwave receiver. After a thorough investigation of available receivers, the Hewlett Packard 8510 automated network analyzer was chosen for its excellent performance characteristics.

THE HP8510 NETWORK ANALYZER AS A MICROWAVE RECEIVER

The HP8510 network analyzer was designed for the measurement and characterization of microwave circuits and components. However, the heart of this

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system is a very capable microwave receiver that has been used to demonstrate the HP8510's suitability as a receiver for far-field antenna measurements, as well as radar cross section measurements. This is possible because the HP8510 can be configured with either a test set or external mixers, and the HP8510 can be used in its fully automated mode or in a more manual mode with an external computer. The HP8510 can also be configured with a time domain option that enables it to obtain down range responses as in the case of compact range or RCS measurements.

The HP8510 exhibits a high degree of capability. The nonaveraged signal sensitivity is better than -90 dBm. The receiver can measure data, using a fast data acquisition mode at a rate of one new data point every millisecond. By utilizing the averaging feature, the sensitivity can be extended to much lower levels with a time penalty of 0.2 msec per average. Data can also be post-processed immediately and displayed in several formats. It is also possible to calibrate out the responses of the reference and test signal transmission paths automatically, thus leaving only the response of the AUT and the near-field probe. The latter cannot be accomplished at the high data acquisition rate, but can be implemented during post processing. Also, the size of the data set taken is unlimited; however, to use the post-processing options of the HP8510 will require limiting the data set to the HP8510 data formats of either 51, 101, 201, 401, or 801 data points.

CONFIGURING THE HP8510 FOR NEAR-FIELD ANTENNA MEASUREMENTS

Figure 1 is a block diagram of the HP8510 configuration used for near-field measurements. Several RF/LO sources and configurations are possible with the HP8510; however the configuration shown enables the best measurement capability. The HP8510 utilizes a dual down conversion technique. The first IF of this system is at 20 MHz and the second IF is at 100 kHz. The first down conversion is usually performed by one of the many test sets compatible with the HP8510. Unfortunately, to preserve the maximum dynamic range of the system, the test set must be closely located to the reference or test signal source, which is impossible in a near-field measurement when the AUT and the near-field probe are remotely located from one another. Instead, external mixers are used to achieve the first down conversion to 20 MHz.

Even harmonic, external mixers are used in the configuration shown. RHG model DMEX 2-18 mixers permit measurements from 2 to 26.5 GHz with a nominal conversion loss of 10 dB over this range. The second harmonic is used from 2 to 14 GHz, and the fourth harmonic is used from 14 to 26.5 GHz. The added conversion loss when using higher harmonics can be approximated closely by: $10 \cdot \log(N)$, where N is the harmonic number. The need to use higher harmonics is due to the bandwith limitation of the fiber optic LO (this will be discussed in detail in the following section). The LO signal level required by the mixers for proper operation is between 0 and 5 dBm.

The RF and LO signal sources are both HP8340 synthesized signal generators. This combination yields the highest signal stability for measuring amplitude and phase, and was first demonstrated in mm-wave network analysis with the HP8510. The measurement stability is derived from the 4 Hz stability of each source. The system phaselock is achieved by strapping the sources together in a master-slave fashion using the 10 MHz reference signal generated by the RF source as shown. Once the HP8510 is phaselocked in this way, the 10 MHz reference signal can actually be disconnected without any adverse effects, because the stability of the sources keeps the system phaselocked without it.

When the HP8510 is used in the fast data acquisition mode, it is only capable of single frequency CW measurements under the control of an external computer/controller. The HP8510 is responsible for the control of the RF and LO sources along with the actual data acquisition, while the external controller is responsible for the initiation of data acquisition through an external trigger input to the HP8510, and is further responsible to read the acquired data out of the HP8510 internal data buffer. Once the HP8510 has been set in the fast data acquisition mode, it disables its internal data acquisition trigger signals and waits for the external controller to send the trigger signals. In this way, the external controller can coordinate the data acquisition with an asynchronous external event such as near-field probe position. This is accomplished, as illustrated in figure 1, by using one IEEE-488 interface to generate a suitable trigger signal, and a second IEEE-488 interface to send control commands to the HP8510 for both set-up and data retrieval. In order to minimize the data acquisition time in this mode, the data is output in a three byte format. The first and second bytes are the magnitudes of the imaginary and real components of the data, respectively, and the third byte is a common exponent. This is the format in which the data is stored internally in the HP8510 buffer and therefore requires no further processing by the HP8510.

FIBER OPTIC LO DISTRIBUTION

The original receiver for the NASA LeRC near-field scanner used a bidirectional LO/IF signal distribution system. A physically large, low loss coaxial cable was used to distribute these signals for both reference and test channel signals. Due to the inflexible nature and significant weight of the coaxial cable used, it was mounted to a special fiberglass arm to support it. The arm has proven to have two undesirable side-effects. In order to move with both the probe cart and the gantry upon which the probe cart rides, the arm was constructed in two pieces connected together with a rotary joint. Two additional rotary joints allow the arm to articulate at the back of the probe cart and at a base pivot point. The rotary joints exhibit a random step function change in phase when they are not rotated continuously. The other side-effect is the side-loading the arm imparts onto the probe cart. The majority of this effect was relieved by a system of springs which generates an opposing force attached to the arm, but the effect is not completely eliminated, and perturbs the position of the probe. A fiber optic distribution system for the LO was purchased to eliminate the need of the arm altogether.

The fiber optic LO distribution system was custom built by Lasertron, Inc. This system provides the distribution of the LO signal from the LO source in the near-field control room to the remotely located reference and test channel mixers in two independent, but identical links. As shown in figure 2, the nominal passband of operation has been optimized for 2 to 7 GHz. The LO signal from the LO source is split and then applied to two independent optical transmitters (OT). The optical signal is carried by ruggedized, multimode fiber optic cables to the optical receivers (OR) located at the reference and test channel mixers, located at the AUT and the near-field probe, respectively. The electrical to optical and optical to electrical conversion losses are virtually corrected for by an internal amplifier in each OR unit.

The light weight and high degree of mechanical flexibility of the fiber optic cable eliminates the need of the fiberglass support arm and the rotary joints. Unfortunately, the IF signal cannot be transmitted by fiber optic cable. The IF signal has a great dynamic range, much greater than that obtainable with a fiber optic link. Therefore, the IF signal is transmitted by a highly flexible, ruggedized, low loss, light weight, custom coaxial cable. The fiber optic cable and the coaxial cable are bound together and hang from the probe tower in a loop with a large radius of curvature for the test channel, and hang straight down from the AUT.

PERFORMANCE OF THE HP8510 NEAR-FIELD RECEIVER

The initial tests of the HP8510 near-field receiver were made with the entire system configured on a bench top. The link between the AUT and the probe was simulated by a variable attenuator. Of greatest concern was the impact of the fiber optic link. Tests were made measuring the phase and amplitude noise of the S_{21} or forward transmission characteristic with and without the fiber optic LO link, and with and without an averaging factor of 10, at several values of S_{21} ranging from -10 to -70 dB at 10 GHz. The results showed that the amplitude and phase noise added by insertion of the fiber optic links could be eliminated by averaging the signal 10 times. The worst case noise fluctuations were ±1.0° in phase and ±0.25 dB with an S_{21} of -70 dBm and an averaging factor of 10. The time per data point was lengthened to 3 msec; however, this represented a factor of three increase in data acquisition speed and a factor of five in phase and amplitude noise over the previous receiver. Without averaging, the HP8510 performed as well as the previous receiver in noise characteristics and increased the data acquisition time by a factor of 10. With the enhanced data acquisition speed, the near-field scanner is now limited by the positioning system.

After installation of the complete system more tests were made. The external controller/computer was interfaced to the positioning system and the HP8510 receiver. The near-field scanner was scanned, and data was taken. Figures 3 and 4 are examples of the near-field phase and amplitude data taken of a precision in-house built reflector. In order to use the display capabilities of the HP8510, it is necessary to adjust the size of the data set to conform to the predetermined data set sizes of the HP8510. The practice in near-field metrology is to take the minimum number of data points necessary; consequently, it is unusual that the number of data points actually taken will correspond to those HP8510 data set sizes discussed earlier. However, by padding the data set with zeroes or truncating the data set, it is possible to fit the data into the next largest data set size. This is how figures 3 and 4 were generated. Further, once the data is in the HP8510, other post-processing features can be used such as the time domain option.

The time domain option was added to the HP8510 to enable the network analyzer to make time domain reflectrometry measurements. By measuring the frequency scanned amplitude and phase response of a circuit or a device, the time domain option executes a fast fourier transform on the data and generates the time domain response. The same FFT function can be used to generate the far-field AUT response from the near-field AUT data, because the near-field and far-field responses of the AUT form a fourier transform pair. Once the near-field data is loaded back into the HP8510, the HP8510 has no way of determining whether the data is frequency swept data or distance scanned data. However, the HP8510 must be fooled into interpreting the data as frequency swept data. This is accomplished by giving the HP8510 the appropriate start and stop frequency corresponding to the start and stop scanning positions. After the HP8510 is provided with this information, the time domain FFT can be executed and the far-field response of the AUT will be displayed on the screen as in figure 5. What is displayed is not truly the far-field AUT response as a function of angle, but rather the wavenumber spectrum of the AUT, which closely approximates the far-field angular response at angles close to boresite.

CONCLUSIONS

An HP8510 automated network analyzer was configured as a microwave receiver for making near-field antenna measurements. The system used a fiber optic LO distribution system to distribute the LO signal to remote harmonic mixers. Single frequency, averaged data acquisition was achieved at a rate of 3 msec per point. The HP8510 was used to display the near-field data and to post-process the near-field data to render the far-field response of the antenna measured without the use of an external computer. The configuration of the system and the techniques for implementing the HP8510 were discussed.

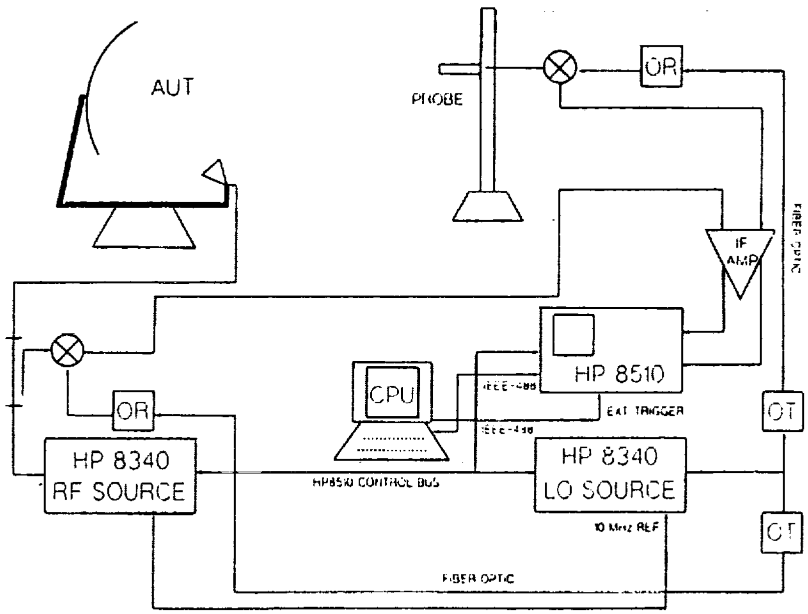

Figure 1.—HP8510 near-field receiver configuration.

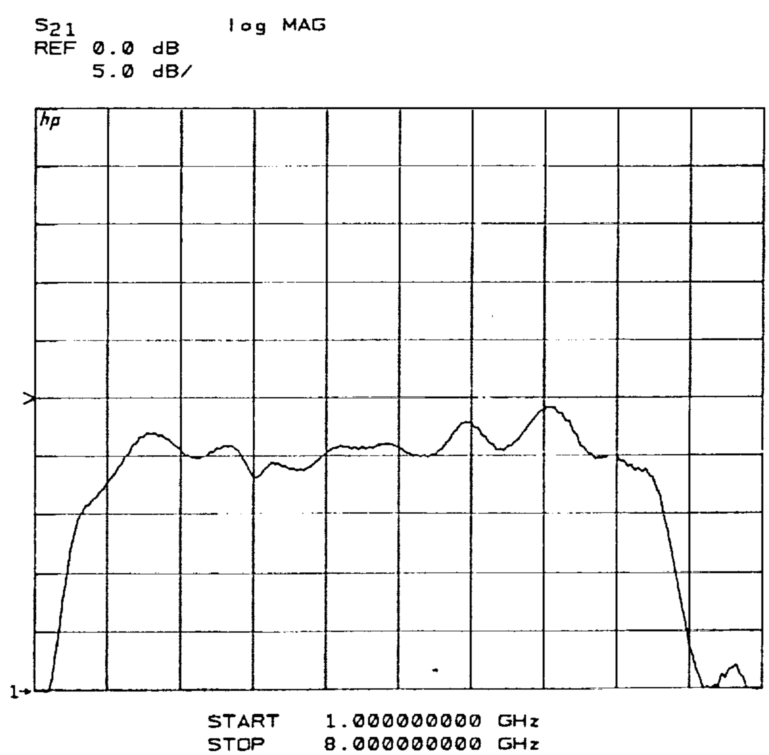

Figure 2.—Fiber optic LO link response.

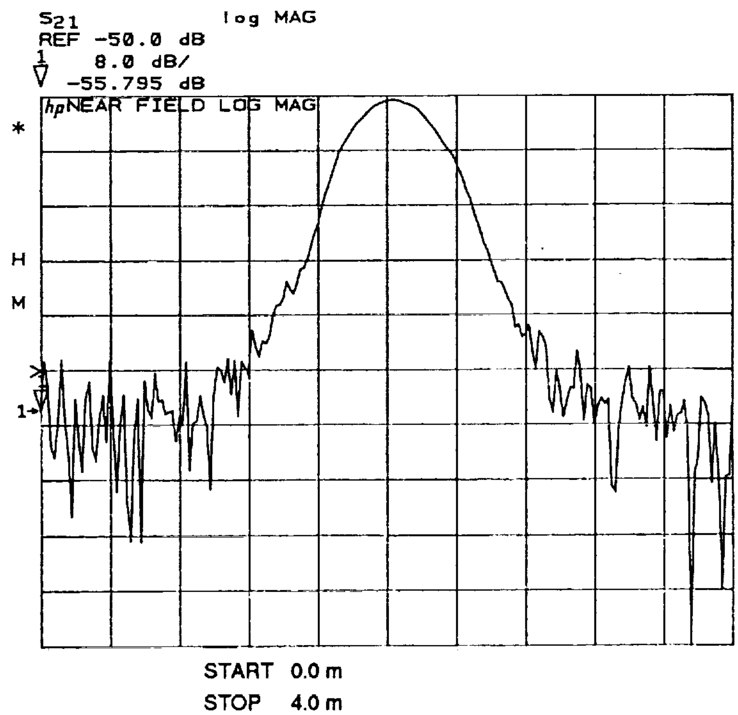

Figure 3.—Near-field amplitude for AUT.

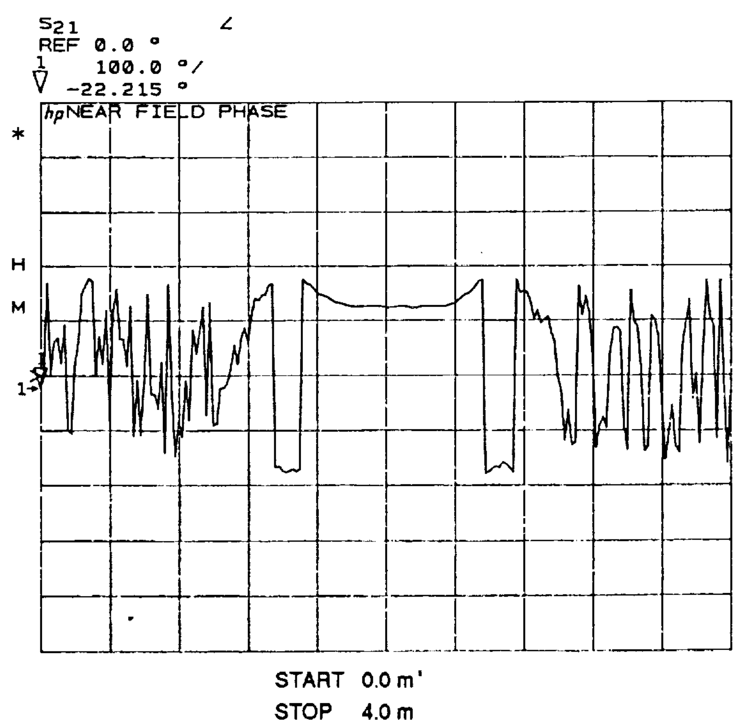

Figure 4.—Near-field phase for AUT.

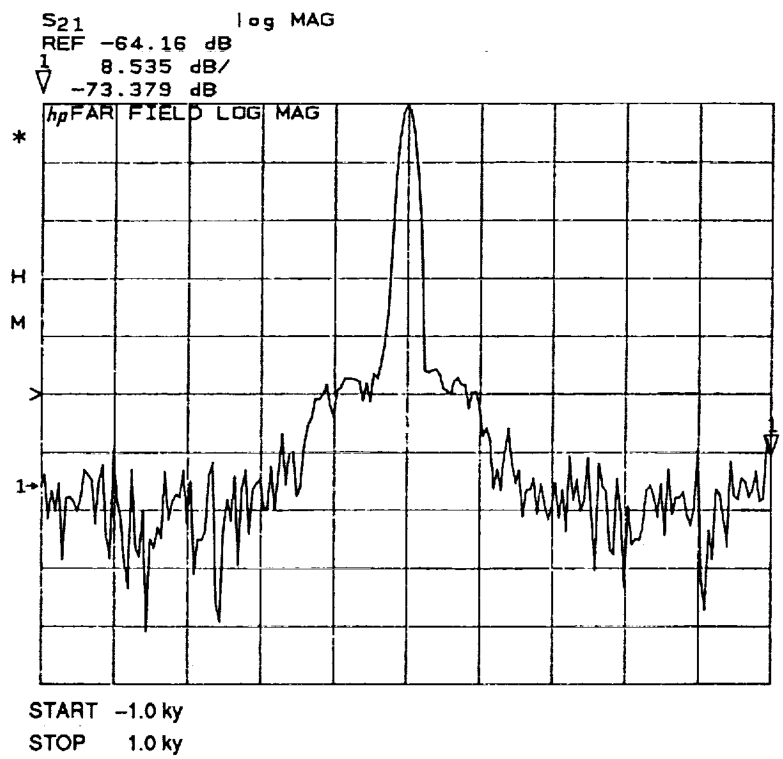

Figure 5.—Far-field amplitude for AUT.

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16. Abstract

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